(*Reprinted from the American Naturalist, November*, 1878.)

PLASTER OF PARIS AS AN INJECTING MASS.[1]

BY SIMON H. GAGE, B.S.,

Instructor in Microscopy and Practical Physiology, Cornell University.

THE necessity for some artificial, colored medium to fill the blood vessels must have been felt by the first anatomists. Indeed, injections were rudely made by Eustachius and Varolius in the sixteenth century (Turner, 1, I, 812).[2]

It was left, however, to De Graaf and Swammerdam to fairly initiate the process in the middle of the seventeenth century (Turner, 1, I, 812).

De Graaf used mercury and colored fluids, and was the inventor of the injecting syringe (2, XVII, 291); but it is to Swammerdam that anatomists owe most, for he introduced the use of colored wax (2, XL, 477 and 1, I, 812). This answers fairly the requirements of an injecting mass, as it may be used in the fluid state, but becomes solid very soon afterward. Upon renouncing anatomy for mysticism, Swammerdam gave his secret to Ruysch, his fellow countryman (2, XL, 477), who perfected the art, and fairly approached in skill and excellence of results the refinements of modern anatomy (1, I, 812, and 2, XXXVII, 143).

About the middle of the eighteenth century, Monro *primus* published an essay on anatomical injections (4), in which were given very precise directions for the manipulation and preparation of the injecting mass. It was composed of wax, tallow, oil and turpentine, colored with vermilion, verdigris or lamp-black (3).

In the latest works which treat of the technology of injections (5, 6 and 7), nearly the same formulæ for injecting masses are given; and except a mere mention of gypsum in Martin (7, II, 99), all coarse masses are solid at ordinary temperatures and must

[1] This paper is based upon investigations made in course of the preparation of a Manual for the Dissection of Cats, by Prof. Burt G. Wilder and the writer.

[2] See list of works referred to at the end of this paper. The first figure designates the number on the list; the last, the page; the middle, Roman numeral, the volume.

be heated before use. The subject must also be thoroughly warmed.[1]

Plaster of Paris has long been used as an injecting mass, in the medical schools of this country at least. It seems to be admirably adapted to this purpose from its well known property of becoming solid when mixed with water.

Although plaster has not the defects of the masses that require warming before use, there are difficulties in its manipulation. I have been unable to find anything upon the matter in books; and gentlemen connected with medical schools say they do not know of any printed directions; but this process of injecting, like other expedients is handed down by tradition from one demonstrator to another. All that I have been able to learn from others of the technology of plaster injections is that the plaster should be mixed to a thin paste with water (with a saturated aqueous solution of arseniate of soda at one mediçal school) and used, uncolored or colored with vermilion or red lead, very quickly before it has time to set.

The lack of precise information as to its manipulation, and the skill and certainty necessary to use simple plaster and water, from its rapid setting, render it hardly manageable by students. Yet it is so simple and excellent for coarse injections that some careful experiments were made, in the anatomical laboratory of the Cornell University during the last college year, to render it practicable, if possible, for the use of students by elucidating the following particulars:

1. The character of the plaster to be used.
2. The proportions of plaster and fluid.
3. The best and cheapest red and blue colors.
4. The means by which the plaster may be kept fluid ten to thirty minutes after mixing without preventing it from hardening finally.
5. The precautions necessary in making permanent the preparations injected with the plaster mass.

(1.) It was found that the very finest plaster is best, and indeed necessary if it is desired to fill the smaller vessels.

(2.) Equal volumes of plaster and fluid give the best results. This forms a very fluid mass which penetrates finely and sets firmly.

[1] According to Martin and Frey (7, II, 101 and 10,174), fine cold flowing injecting masses may be made by dissolving copal and mastic resin, with a small proportion of wax, in sulphuric ether, and coloring with red lead; or by dissolving the finest red sealing-wax in absolute alcohol. These masses harden as soon as the ether or alcohol soaks into the tissues.

A thicker mass is much more difficult to manage. A slightly greater proportion of fluid may be used if the finest vessels are to be filled. The fluid includes all the liquid used in mixing the mass; viz, coloring liquids, restrainers and water.

(3.) As to the red and blue colors, there are several that answer admirably. For red, vermilion or red lead ground in a mortar with a little water to get rid of lumps may be added in sufficient quantity to give a bright color. A saturated aqueous solution of magenta or red aniline is the easiest to use of all the red colors. It does not diffuse and color the tissues as one might expect, but colors the walls of the vessels a very bright red. An ammoniacal solution of carmine is, however, the best red. A sufficient quantity of this is added to the mass, and then the carmine is precipitated with fifty per cent. acetic acid. The acid should be poured into the colored mass, with constant stirring, till the color changes to the bright red of dry carmine, and there is a distinct odor of the acid. It is necessary to precipitate the carmine, as an alkaline solution diffuses through the walls of the vessels and stains the surrounding tissue. The advantage in precipitating the carmine in the mass is its uniform diffusion. The same method is employed in coloring red the finest gelatin masses for histological injections (9, 10 and 11).

A saturated solution of Berlin blue is the best blue, but as this is difficult to prepare (8, 403, 9, 164 and 10, 180), the ordinary Berlin or Prussian blue of the shops will answer if it is ground with water to a homogeneous paste. The simplest blue is, however, a saturated aqueous solution of blue aniline.

The aniline colors are the easiest to use, as it is simply necessary to add to the mass a sufficient quantity of the solution to produce the desired tint.[1]

(4.) It has been known a long time that if alum or borax is burned with gypsum, the resulting plaster will not set for three or four hours after mixing, but will finally set nearly as hard as marble (12). It is said by Tomlinson (13, I, 829) that ordinary plaster may be kept fluid four or five hours after mixing with water by adding a little *size* or beer; and it is a matter of common experience that the greater the proportion of water the longer it takes the plaster to set. It is necessary to give the mass a cer-

[1] Leamon's red and blue aniline dyes answer very well, and may be bought at any drug store.

tain consistency in order to have the resulting injection successful, therefore the amount of water could not be increased sufficiently to retard the setting over four or five minutes. As to the alum-plaster, it is difficult to obtain, and has the same objection as the mass to which *size* has been added; viz, it is too long in setting, for it is often desirable to begin a dissection in comparative anatomy almost immediately after the injection has been made.

It was noticed that a mass colored with carmine solution and afterwards acidulated with acetic acid remained fluid a much longer time than when colored with a red or blue with which no acid was used. Experiment showed that plaster mixed with an equal volume of ten per cent. acetic acid remained fluid ten to twenty minutes. The time was increased when carmine solution was used with the acid, as in practical injections, but not when any other colors were added. It was also found that if the plaster was mixed with either of the following solutions, instead of water, the setting was retarded ten to thirty minutes: A ten to twenty per cent. aqueous solution of alcohol or glycerine, or a ten per cent. solution of arseniate of soda. Either of these restrainers may be used with either of the colors. The arseniate and the acetic acid make the plaster friable, but the others do not.

It is important to state that a mass which has been treated with a restrainer may be kept perfectly fluid much longer by agitation. This is also true of plaster and water, but not in so great a degree.

In all of the experiments the plaster, after being thoroughly mixed with the fluid, was poured into small paper boxes like those used in imbedding for microscopical sections. It was found in practice that the plaster hardened much quicker in the blood vessels than in the paper boxes. This is probably because the restrainers and all superfluous liquid soak into the tissues, leaving only the amount of water necessary to crystallize the plaster.

(5.) If one desires to make a *permanent* alcoholic or dried preparation of any part or organ injected with plaster, the aniline colors must not be used, as they are not enduring. The alcohol should be seventy-five per cent. or stronger, and slightly acidulated with acetic acid (alcohol 200 parts, acid 1 part) to preserve the brightness of the Berlin blue and the carmine red (10, 202).

The part to be preserved should not be placed in alcohol till the plaster has become thoroughly hardened. An hour will usually suffice.

Practical Application of the Plaster Mass.—It will be readily seen that the plaster mass is far superior to a wax mass for ordinary work. It is simply necessary to mix it well with an equal volume of fluid; and the subject needs only to be bled. Wax involves great expense and trouble in preparation, and both it and the subject must be thoroughly warmed before the injection can be made (7, II, 100 and 3). The warming is objectionable especially with cold blooded animals.[1]

Plaster is also very neat, it never softens, but makes the injected vessels like cylinders of stone. It penetrates very finely, filling arteries half a millimeter in diameter, and has a great range of uses. It is well adapted to fill various ducts, like the thoracic, pancreatic, etc. The valves in the veins, the semilunar valves of the aorta and pulmonary artery may be most satisfactorily demonstrated with it, and with a little care and experience the action of the auriculo-ventricular valves of the heart may be nicely shown.

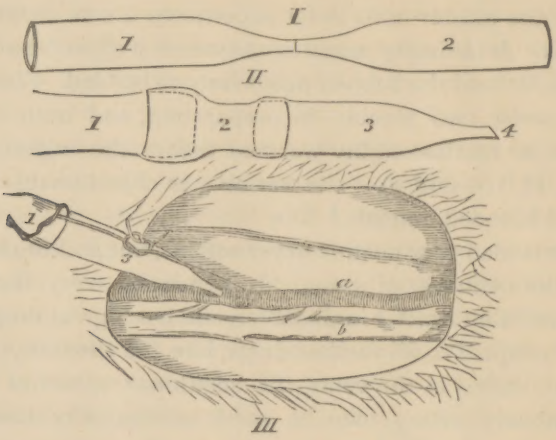
Vessels or ducts injected with plaster may be dissected out neatly, and placed on cardboard to dry. The appearance of the dried preparation is nearly like that of the fresh specimen, as the plaster prevents shrinkage. Preparations so made will last indefinitely if they are well poisoned with arseniate of soda before drying. Specimens injected with plaster colored with Berlin blue and carmine, have kept three months in slightly acid alcohol without the least change.

The accompanying diagrams are introduced to show the cheapness and simplicity of an injecting apparatus, and its practical application in plaster injecting.

An 8-ounce lead or britannia syringe, with a leather packed piston, works very well indeed and costs less than one dollar. The canula is so large, Fig. II, 1, that it cannot be put into the vessels. Fine canulæ for this purpose may be made by any per-

[1] It is objectionable to warm thoroughly a mammalian animal after death, as it greatly hastens decomposition. It is particularly objectionable to warm cold-blooded animals, for the warm water, into which they must be put, acts as a powerful stimulus, causing general tetanus, unless one waits half a day or a day after apparent death. The tissues, especially of *amphibians*, are greatly softened by the warm water, in fact partially cooked. It is also a great deal of trouble to warm the animal and the mass in summer.

son out of a small glass tube, as shown in Fig. I. The fine canula is connected with the canula of the syringe by means of a tightly-fitting rubber tube, Fig. II, 2.



EXPLANATION OF THE DIAGRAMS.

FIG. I.—1-2, a glass tube 6 mm. in diameter is evenly heated in the center over an alcohol or Bunsen flame, and drawn out till it is only 1–2 mm. in diameter. A scratch is then made with a fine file and the two are broken apart.

FIG. II.—1, the large canula of the syringe; 2, rubber tube serving to connect this large canula to the fine canula, 3; 4, the oblique end of the fine canula, made by carefully grinding with a fine wet file. The sharp edges at both ends of the glass canula may be removed by cautiously heating in the flame.

FIG. III.—The artery and vein of the left leg are exposed, and the artery is represented as ready for injection. To inject the body it is simply necessary to change the direction of the canula. *a*, femoral artery; *b*, femoral vein; 1, surgeon's knot on the large end of the canula; 2, insertion of the canula into the artery; 3, knot connecting the strings round the artery and the large end of the canula.

All the knots shown in the figure should be hard knots like 3.

In order to inject, the given vessel or duct is exposed and a longitudinal slit made in it. The fine canula connected to the rubber tube, Fig. III, is put into the vessel, and a string tied in a hard knot around the vessel so that it will press on the canula. One end of this string is then tied to another string coming from the large end of the canula, Fig. III, 1. This prevents the canula from slipping out of the vessel.

After the canula has been tied into the vessel, the injecting mass is prepared. Let it be for the arterial system of a cat. 100 cc. of the finest plaster of Paris is put into a clean dish, and 84 cc. of a ten per cent. aqueous solution of alcohol, glycerine

or arseniate of soda is added, and the whole well mixed. Then 8 cc. of carmine solution is stirred into the mass, and finally 8 cc. of fifty per cent. acetic acid is poured in with constant stirring. The fine canula and rubber tube are filled with water to avoid getting air into the vessels. The syringe is then filled with the prepared plaster mass and the large canula of the syringe is connected to the fine canula by means of the rubber tube. The pressure should be *steady* and *continuous*. There is very little danger of bursting arteries if the pressure is steady.

Before the injection is commenced, a string should be put around the artery beyond the end of the canula and loosely knotted with a surgeon's knot. (In a surgeon's knot the string is put through the loop twice as shown in Fig. III, 1.) As soon as no more mass can be forced into the vessels the surgeon's knot should be tightened, and the fine canula and syringe thoroughly washed with water. All the dishes used in making the injection should be washed immediately before the plaster hardens. The most scrupulous cleanliness is necessary to prevent lumps of hardened plaster from clogging the syringe or the vessel which is being injected.

In case veins are to be injected they should be, as far as possible, emptied of blood, and the injection must be made from some peripheral vessel like the femoral or jugular veins, on account of the valves. It is well if the injection is made into the femoral vein, for example, to have the jugular open to allow the blood to flow out as the plaster is forced in. There is no danger of the plaster running out, for it cannot pass the valves.

As a rule a dissection may be begun in half an hour after the injection.

FORMULÆ FOR PLASTER MASSES.

The amounts given are those necessary for an ordinary cat, and cost two to five cents:

1. Finest plaster of Paris.....100 cc.
   Red lead or vermilion.....50 grams.
   Either of the following restrainers.....100 cc.
   Ten to twenty per cent. aqueous solution of alcohol or glycerine, or a ten per cent. solution of arseniate of soda.
2. Plaster.....100 cc.
   Restrainer..... 84 cc.
   Ammoniacal solution of carmine..... 8 cc.
   (Dry carmine 1 gram, ammonia 2 cc. Grind the two in a mortar and add 22 cc. of twenty per cent. glycerine,)
   Fifty per cent. acetic acid..... 8 cc.

3. Plaster..... 100 cc.
   Saturated aqueous solution of magenta or aniline red..... 25 cc.
   Restrainer..... 75 cc.

4. Plaster..... 100 cc.
   Berlin blue in powder..... 2 grams.
   Restrainer..... 100 cc.

5. Plaster..... 100 cc.
   Saturated aqueous solution of aniline blue..... 10 cc.
   Restrainer..... 90 cc.

WORKS REFERRED TO.

1. Turner, W. Article Anatomy in Encyclopædia Britannica, 8th and 9th editions.
2. Biographie Universelle. Ancienne et Moderne (Michaud). Paris, 1854.
3. Parr, Bartholomew. The London Medical Dictionary. Article Injections. London, 1809.
4. Monro *primus*. An essay on Anatomical Injections. Inserted in the essays of the Society of Edinburgh, 1741.
5. Dunglison's Medical Dictionary, Revised edition. Article Injections.
6. Dictionnaire de Medicine, etc., 14th edition. Par E. Littré et Ch. Robin. Article Injection. Paris, 1877.
7. Martin, Philip Leopold. Die Praxis der Naturgeschichte. Drei Theile. Weimar, 1869–1878.
8. The American Naturalist, Vol. XI.
9. Schæfer, E. A. Histology and the Microscope. Philadelphia, 1877.
10. Frey, Dr. Heinrich. The Microscope and Microscopical Technology. New York, 1872.
11. Ranvier, Louis. Traité technique d'Histologie. Paris, 1875.
12. Laboulaye, M. Ch. Dictionnaire des Arts et Manufactures, 3d edition. Article Plâtre. Paris.
13. Tomlinson. Cyclopædia of useful Arts and Manufactures. Article Gypsum. London and New York.